Automated Rover Sequence Report Generation

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Abstract— A web-based rover mission operations report and its various elements are described. The system was used for documentation of the Field Integrated Design and Operations (FIDO) rover May 2000 field test and results from the field test are provided. Implementation of automated sequence report generation for the operations report is explained in detail.

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1. INTRODUCTION

Sequence generation for Mars Rover missions includes many steps which cumulatively can take a significant amount of time to complete. It took about 16 hours to complete all of the steps to generate one sequence to be uplinked to the 1997 Mars Pathfinder mission Sojourner rover [1], [2], [3]. It is desired to reduce the time to generate one rover sequence in future missions.

The sequence generation process starts with the receipt of the downlink data from Mars. Engineering and science data is processed, placed in databases, and analyzed. An engineering team determines the status of the rover. Scientists evaluate scientific data and consider what they would like the rover to do next. Planning meetings are held to decide what activities to include in the next rover sequence and then a sequence generation team generates the rover sequence to best satisfy the desired scientific goals. The sequence is checked to verify its safety and resource constraints and then uplinked to the rover. But the process is not complete with the uplink to the rover. The sequence, issues, and decisions that went into the generation of the sequence still need to be documented in reports while the information is still current. It might take further hours to generate all the necessary sequence documentation.

This paper describes a web-based operations report system for Mars rover missions and the automated generation of reports for sequences. The purpose is to reduce the documentation time for each sequence and to make it easy to access downlink data products and uplink sequence information. Automatic generation of information for the reports reduces the time to generate the documentation, ensures accurate information, and can provide more information than could be generated by hand.

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The operations report is associated with the Web Interface for Telescience (WITS) [4]. WITS is used to generate the command sequences and is used to automatically generate the sequence reports and the SeqPos report, described below.

The operations report system described in this paper was used in the Field Integrated Design and Operations (FIDO) rover May 2000 field test. The field test was used to evaluate surface operations scenarios for Mars rover missions. The rover was at an undisclosed location in the Nevada desert and commanded from the Jet Propulsion Laboratory via satellite link for two weeks. Results from the field test are provided.

The FIDO rover is a prototype rover equipped with instrumentation designed to simulate the Athena Payload for the 2003 Mars Exploration Rover mission [5]. Stereo cameras on the rover's mast and body are used to image the surrounding terrain. An instrument arm places a microscopic imager on selected surface targets. A drill is used to extract rock core samples. An infrared point spectrometer on the mast is used to characterize the terrain.

2. OPERATIONS REPORT

The operations report is a web page which provides access to related reports. It provides information associated with rover operations including downlink data products and uplink sequences. Other reports might be generated for other aspects of a mission.

The operations report organizes documentation about uplink sequences and associated information. A screendump of the operations report for the FIDO field test is shown in Figure 1. The operations report is a web page organized into three frames. The left frame has links to specific reports. In Figure 1, the left frame has sections for each of three phases of the field test. The middle frame has information associated with the selection in the left frame. In Figure 1, the middle frame has the information resulting from selecting the Sequence Reports link in the left frame. The right frame has information associated with a selection in the middle frame. In Figure 1, the right frame has an initial default panorama image from the field test.

The Sequence Summaries link provides access to the sequence summary reports. Selecting it causes the list of summary reports, one per sequence, to be listed in the middle frame. Selecting a summary report link causes it to be displayed in the right frame. A sequence summary report provides notes from the operators about the sequence such as scientist goals and explanations for the different commands in the sequence. All the information in a sequence summary report is entered directly by the operator. It was found during the field test that a better process for generating sequence

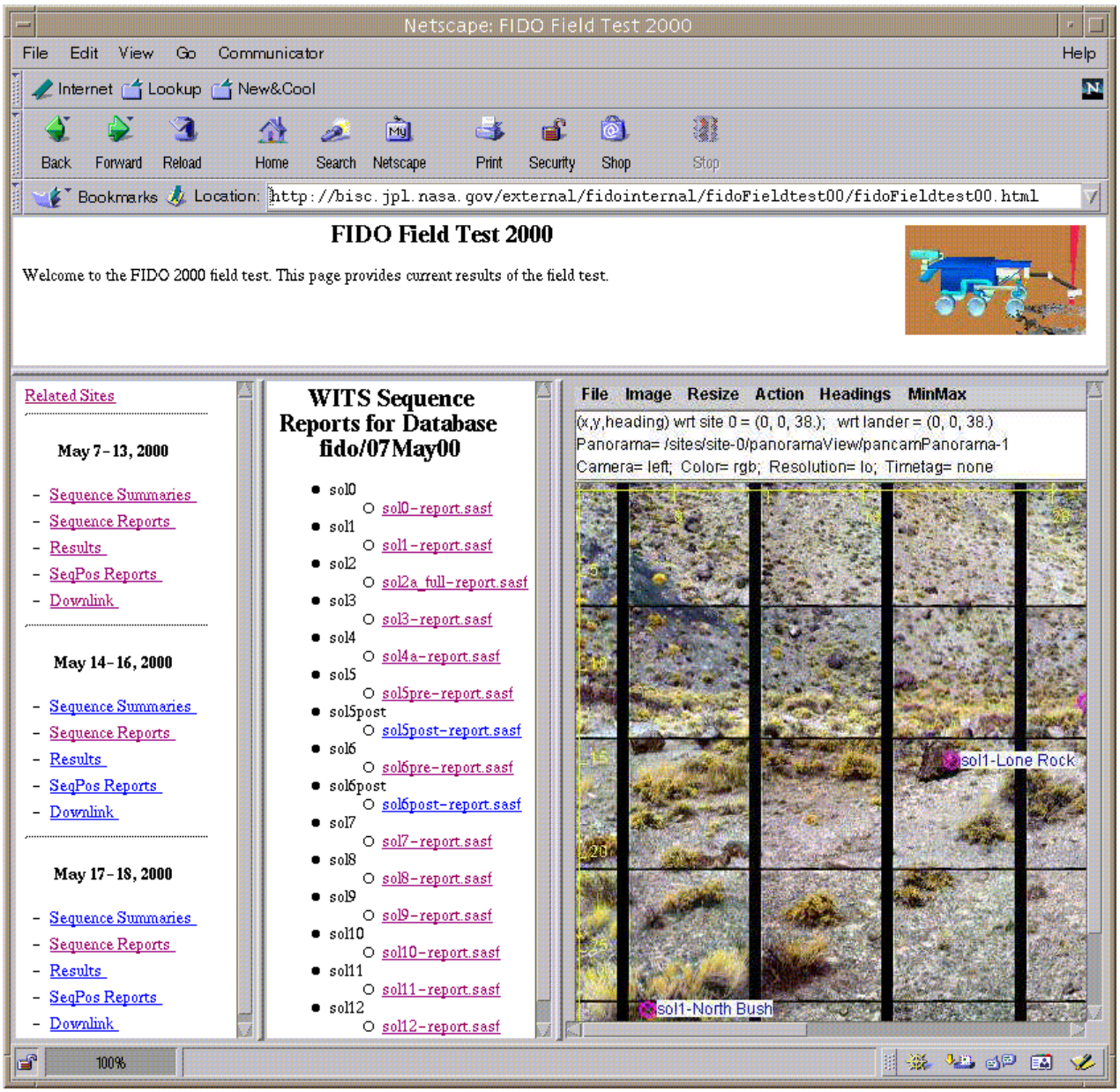

Figure 1. Operations Report

summary information was needed. Often there was insufficient information in a sequence summary report to figure out the motivation for the sequence and the decision process used to generate it.

The Sequence Reports link provides access to the sequence reports. Selecting it causes the list of reports, one per sequence, to be listed in the middle frame. Selecting a report link causes the sequence report to be loaded with its own frame structure. The automatic generation of sequence reports along with examples are discussed in section 4.

The Results link provides access to processed downlink data products. The data products are organized in a file system database. The database is described in section 3. Currently, selecting the Results link causes the browser to display the contents of the results path of the database. By selecting the displayed links, the user can navigate to any downlink data product and view it.

The SeqPos Reports link provides access to the SeqPos report. The SeqPos report organizes the downlink data products by the sequences which generated the data. The SeqPos report is automatically generated via a menu selection in WITS. The report consists of HTML files which are generated. Selecting the SeqPos link causes the downlink data to be listed in the left frame as organized by sequences which generated the data, as shown in Figure 2. For each sequence that was uplinked to the rover, downlink results are provided starting at the position that rover was at when it began executing the sequence and ending with all the data at the position where the rover was when it finished executing the sequence. Selecting an instrument in the left frame causes the data sets for that instrument at that site and position to be listed in the mid-

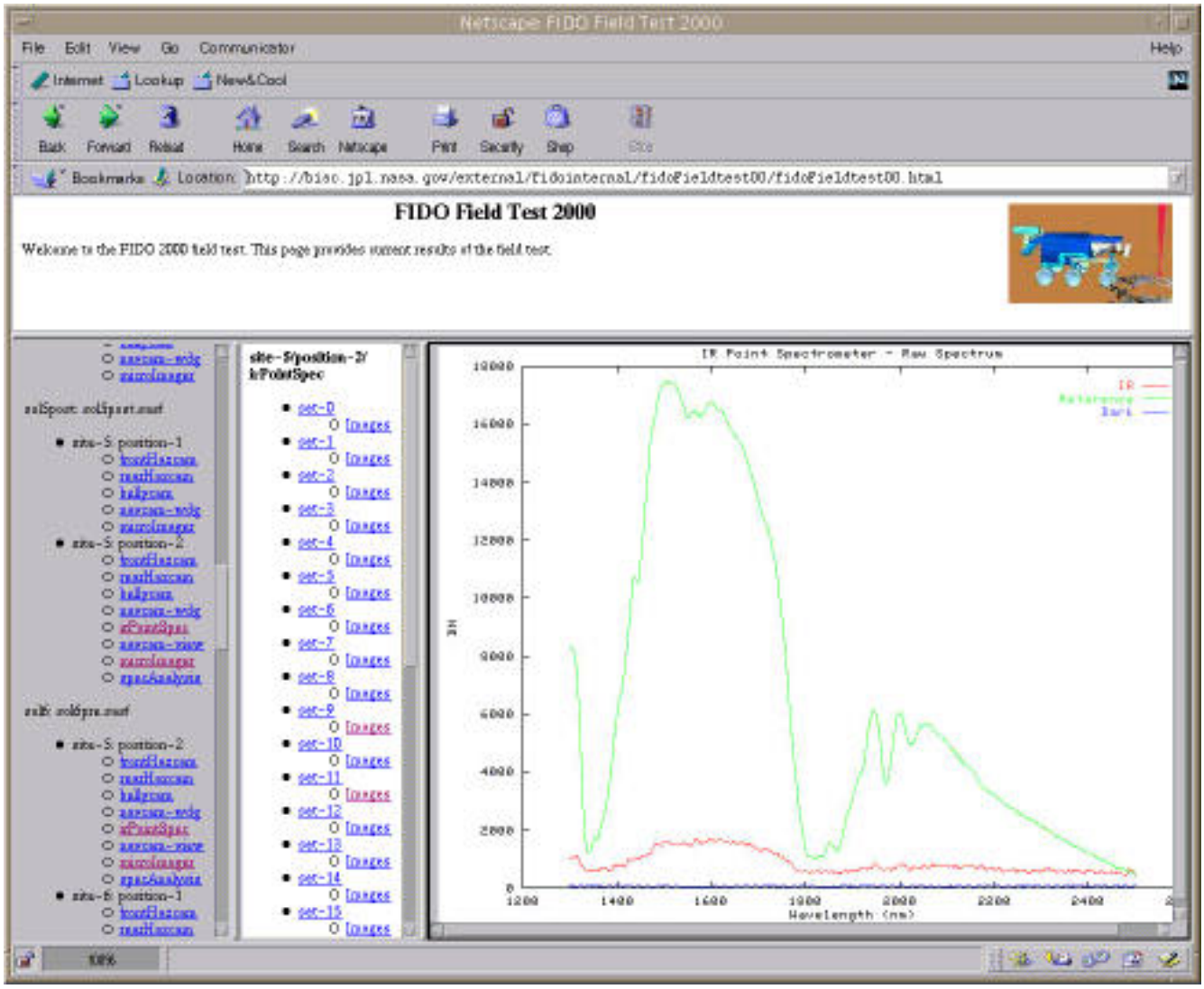

Figure 2. SeqPos Report Showing IR Point Spectrometer Data

dle frame. Selecting the Images link causes the list of images from that data set to be shown in the right frame (not shown in the figure). Selecting an image causes it to be displayed in the right frame. Figure 2 shows a plot for the IR Point Spectrometer (irPointSpec in left column) at site 5, position 2, and data set 9. The downlink data for the position where a rover starts a sequence is listed twice: once for the starting position of the sequence and once with the previous sequence since the position is the ending position for that sequence. The SeqPos report may be modified in the future to only list downlink data with the sequence that actually generated it.

The Downlink link provides access to raw, unprocessed, downlink data. This information is usually not needed.

3. Database Structure

The WITS database is a structured file system. The database includes uplink sequence generation information as well as downlink data products. Downlink data is automatically processed and placed in the correct place in the database using the Parallel Telemetry Processor (PTeP) [6]. Information in the database is used by WITS for sequence generation and for automated report generation. The structure for the processed downlink data product results is given below.

results

- aerial (images taken from orbit or during descent to the surface)
  - alt-1 (images from one altitude)
  - alt-n
- sites
  - site-1 (one site)
  - site-n
    - 3dView (3D view information for this site)
    - overheadView (Overhead view information for this site)
    - panoramaView (Panorama view information for this site)
    - position-1 (a position within a site)
    - position-n
      - instrumentName (directory with data for this instrument)

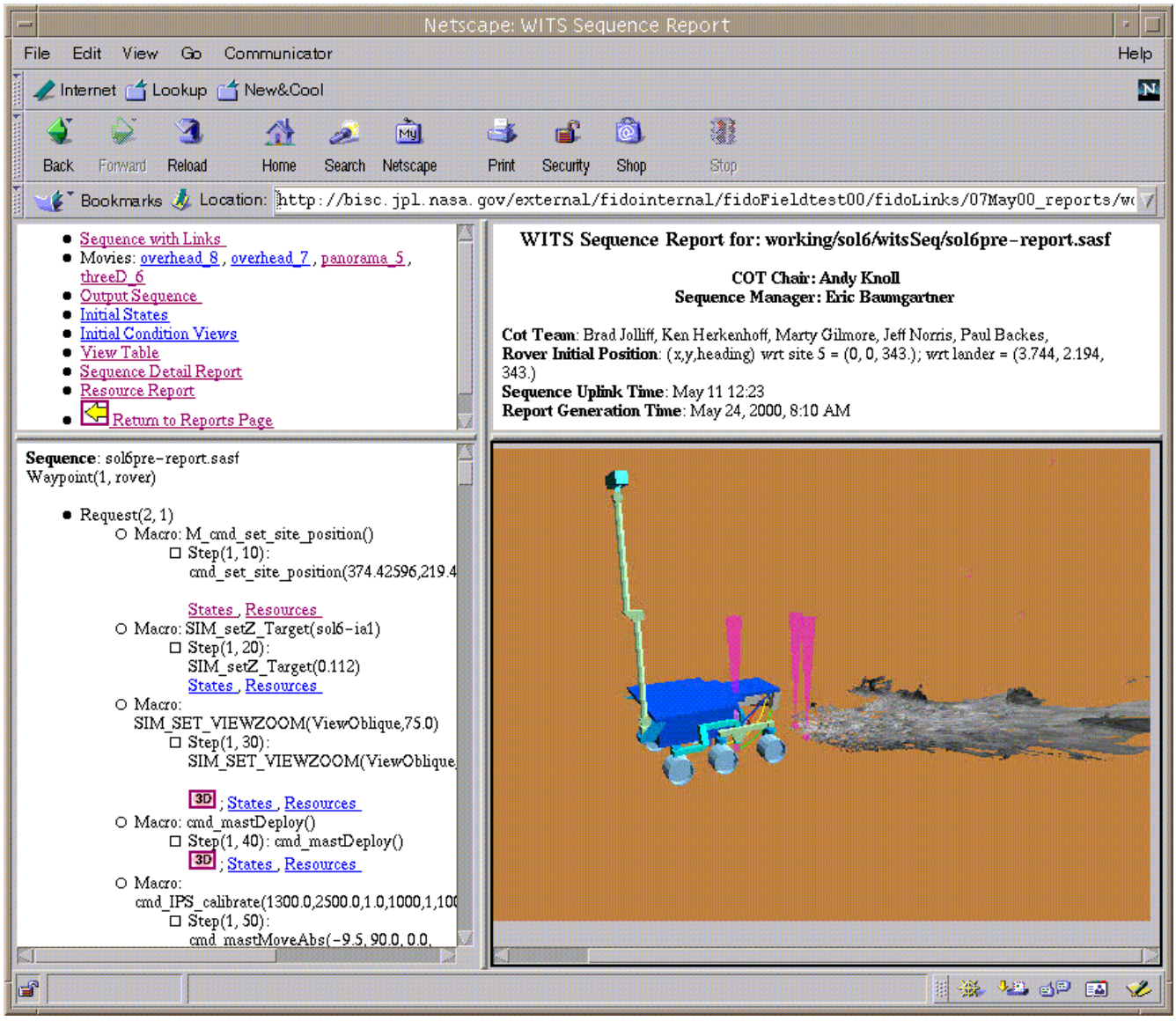

Figure 3. Sequence Report

4. Sequence Report

A sequence report provides detailed information for a sequence. The report, consisting of numerous HTML and jpeg image files, is automatically generated via a menu item in WITS. An example report is shown in Figure 3.

WITS Sequence Elements

WITS is used by an operator to generate a command sequence which will be uplinked to the rover. The various elements of information associated with a sequence which are saved in the sequence report are described here. Various windows providing numerous features are provided by WITS, including the Sequence window which is used to generate a sequence. Descent, Overhead, Panorama, Wedge, 3D, and Instrument Data views display downlink data.

A sequence has a hierarchy of elements: Waypoint, Request, Macro, and Step. Waypoints, Requests, and Macros can have multiple lower-level elements in them. A Step has a single command that will be uplinked to the rover. The WITS sequence holds more information than is sent to the rover. WITS generates an output sequence including only steps which will be sent to the rover.

System states and resource utilization are stored for each Step of a sequence. The states include the planned rover position and heading, instrument arm angles, and mast angles. The resources computed at each step of the sequence include duration, energy, channelized data volume, and non-channelized data volume. Channelized data is the result of a command and is saved for downlink at the next downlink opportunity. Non-channelized data is stored in a heap which is downlinked only when a command specifies to include the data in the downlink. The resources for each step are computed and cumulative resources are computed and stored at each step for the current Macro, Request, and Sequence. WITS generates a resource report which gives the details of the resource utilization for each Step, Macro, Request, and the sequence.

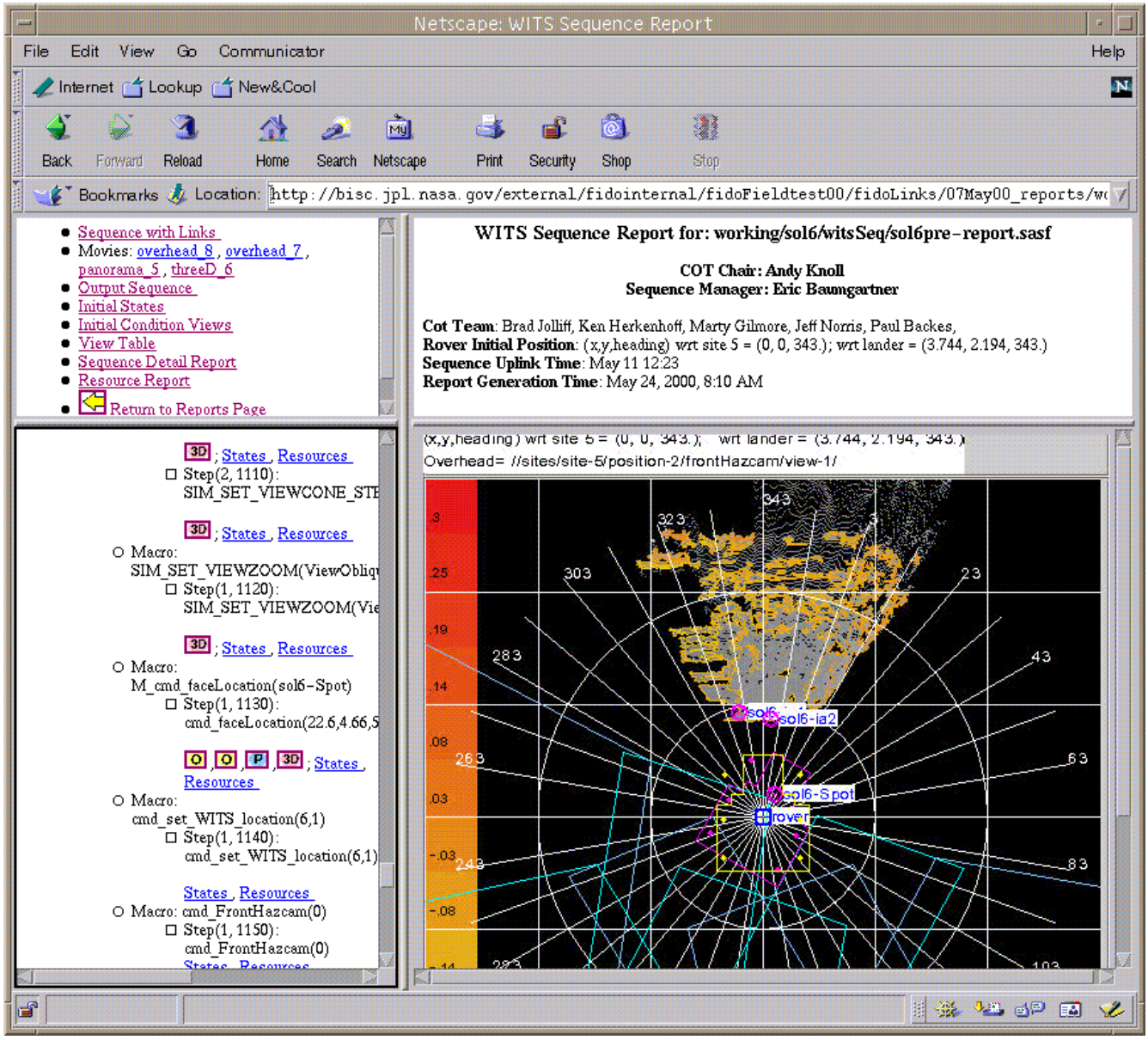

Figure 4. Sequence with Links Page with Step Overhead Icon Selected

WITS provides state visualization for visualization of the rover state at any step of the sequence. When the operator selects a Step in the sequence in the Sequence window, the rover state after that step of the sequence is displayed in all of the views.

Automated Sequence Report Generation

A sequence report is automatically generated by selecting a menu item in the WITS Sequence window. There are no additional inputs by the operator. A directory is created in the database and numerous HTML and jpeg files are automatically generated and placed in the directory.

The report generator first creates information for the whole sequence. The output sequence is generated from the WITS sequence. The initial rover states are written to a file. The detailed resource report for the sequence is generated. The initial condition views are generated. The initial condition views are jpeg images of all WITS views with the rover at its initial condition state.

The report generator then creates the information that is dependent on the specific steps of the sequence. The generator steps through the sequence and stores the information needed for each step. This step information includes states and resources and jpeg images of the views. The jpeg images of the views are automatically captured and show the state of the rover displayed in the open views. Only views relevant to the step type are saved for a Step. After all the information for the steps is generated, then the separate types of pages which depend on the steps are generated.

The resulting sequence report is shown in Figure 3. Four frames are used. The upper right frame has static information about the sequence including its name, operators, and rover initial position. The upper left frame has links which control

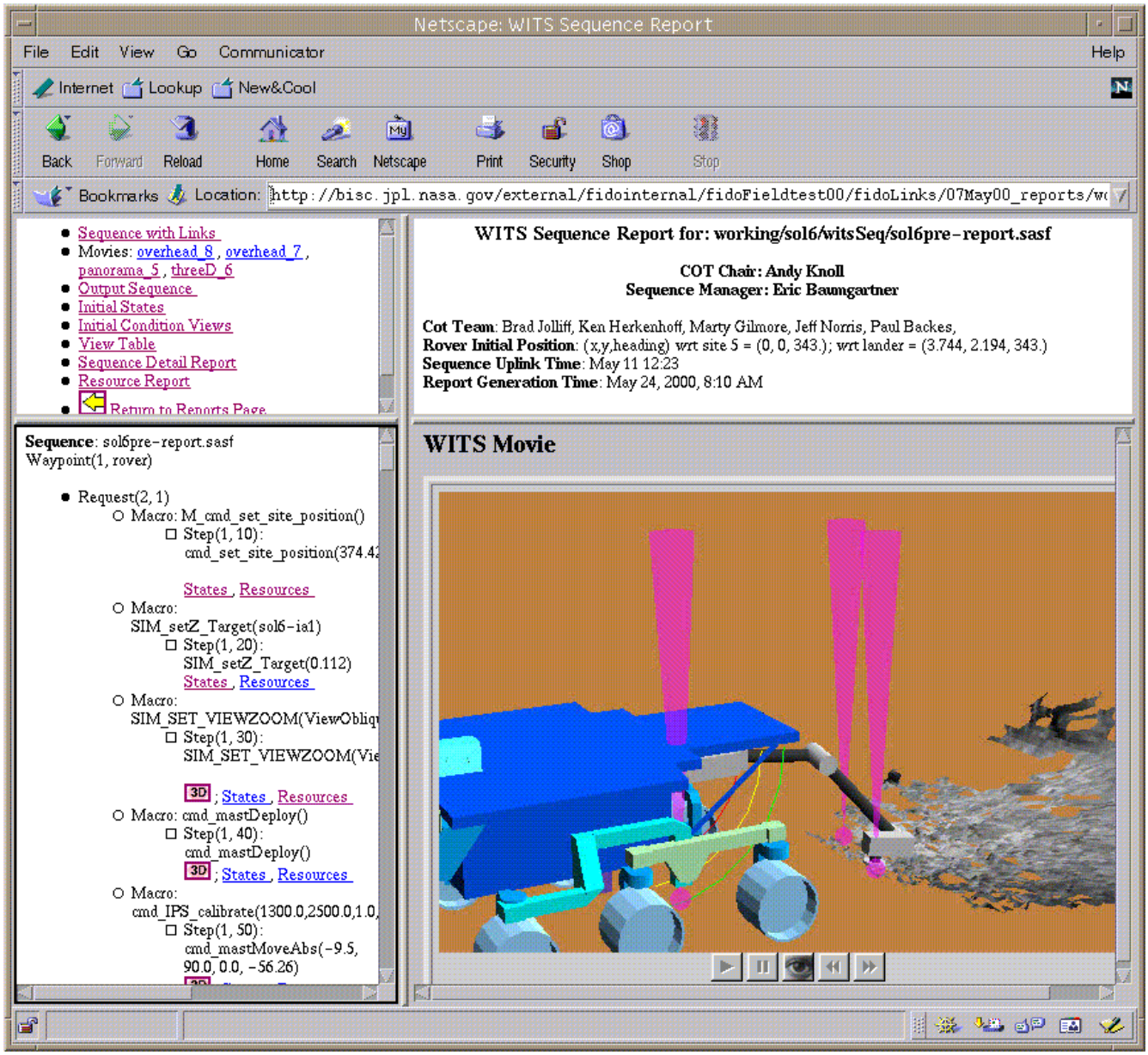

Figure 5. Sequence Report Movie

what information is shown in the bottom left frame. The bottom right frame has information as selected in the bottom left frame.

The Sequence with Links page shows the WITS sequence with its hierarchical elements, as shown in Figure 3. Steps have the incremented step labels, commands with parameters, States and Resources links, and links to the view images which relate to the Step. The States link causes the planned rover states at the end of the Step to be displayed in the bottom right frame. The states include rover position and heading, instrument arm angles, and mast angles. The Resources link displays the start time and the resources after the Step including duration, energy, channelized data volume, non-channelized data volume, and total data volume cumulative for the Step, Macro, Request, and Sequence. There are icons for the 3D view, Panorama view, Wedge view, and Overhead view. If a jpeg image of a view was saved for the step, then its icon is listed with the step. The icons are links to the images. Selection of a view icon causes the jpeg image to be placed in the bottom right frame. An example showing an Overhead image is shown in Figure 4.

Movies of Overhead, Panorama, and 3D views are provided. Javascript programs are generated for the movies. Selection of the desired movie in the upper left frame causes the movie to the played in the bottom right frame. Figure 5 shows a 3D view movie.

Selection of the Output Sequence link causes the output sequence to be displayed in the bottom right frame. Selection of the Initial States link causes a complete list of the rover's initial states to be displayed in the bottom right frame including all states downlinked from the rover. Selection of the Initial

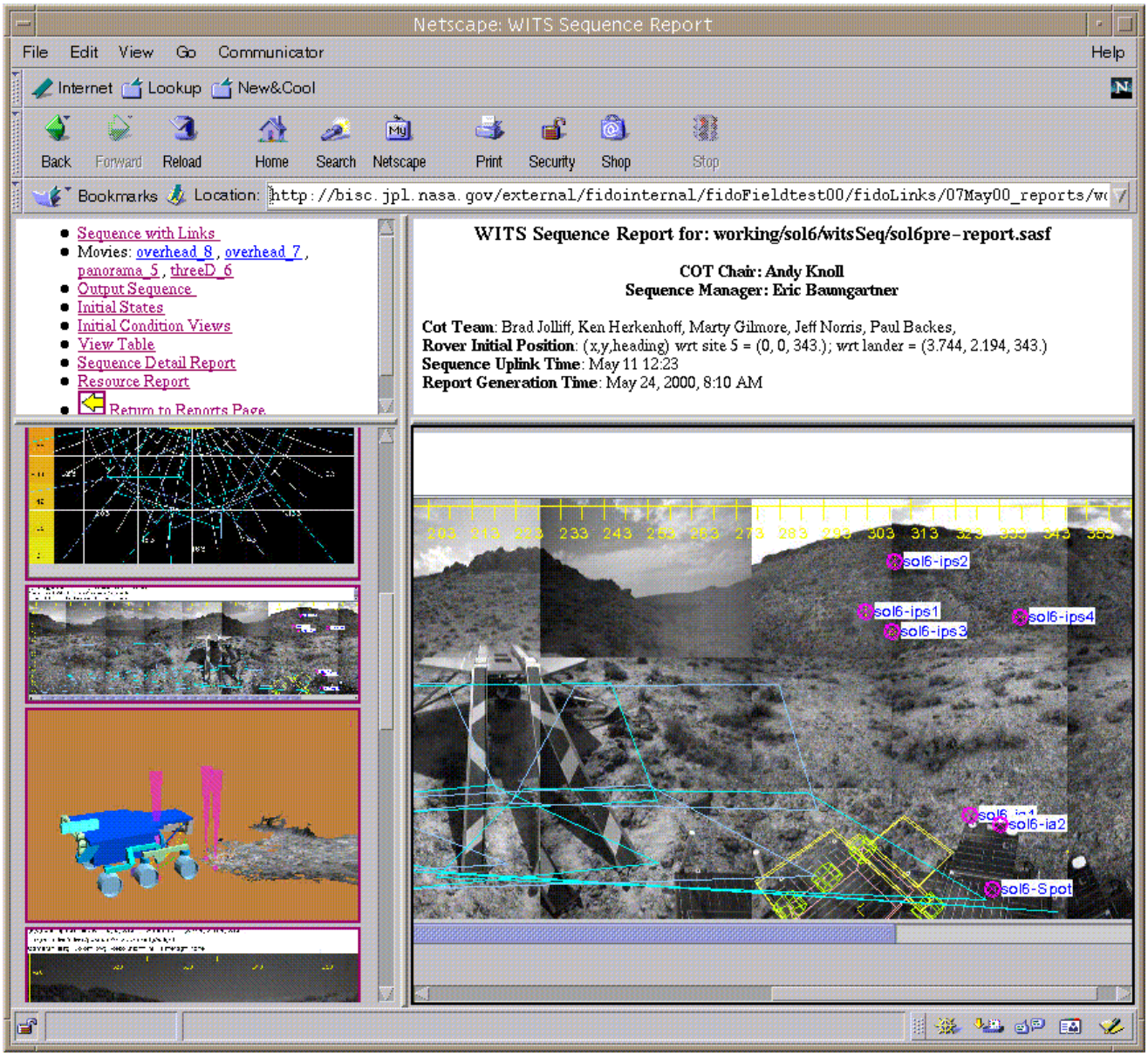

Figure 6. Sequence Report Initial Condition Views

Condition Views link causes the jpeg images of all the WITS open views, showing the rover at its state at the beginning of the sequence, to be displayed in the bottom left frame at a constant width. Selection of one of images causes the full-size image to be displayed in the bottom right frame. Figure 6 shows the sequence report with the Initial Condition Views link selected in the upper left frame, the Panorama view selected in the bottom left frame, and the full-size Panorama view shown in the bottom right frame.

Selection of the View Table link causes all of the stored jpeg images of the views to be displayed in the bottom left frame separated by their associated Steps. Selection of one of the images causes the full-size image to be displayed in the bottom right frame, as shown in Figure 7.

Selection of the Sequence Detail Report link causes the full sequence with all of its hierarchical elements to be displayed in the bottom left frame. Step Resources and States links are provided which cause the resources and states to be displayed in the bottom right frame in a similar manner to the Sequence with Links page. A difference from the Sequence with Links page is that instead of displaying only image icons, the actual jpeg images are displayed with the steps. Selecting an image causes its full-size version to be shown in the bottom right.

Selection of the Resource Report link causes the detailed resource report to be displayed in the bottom right frame.

5. Conclusions

Automated generation of report documentation can save significant time in the rover sequence generation process. Also, more detailed information can be provided with reduced risk of erroneous information. An area that requires further work is in making note taking for sequences more efficient. A

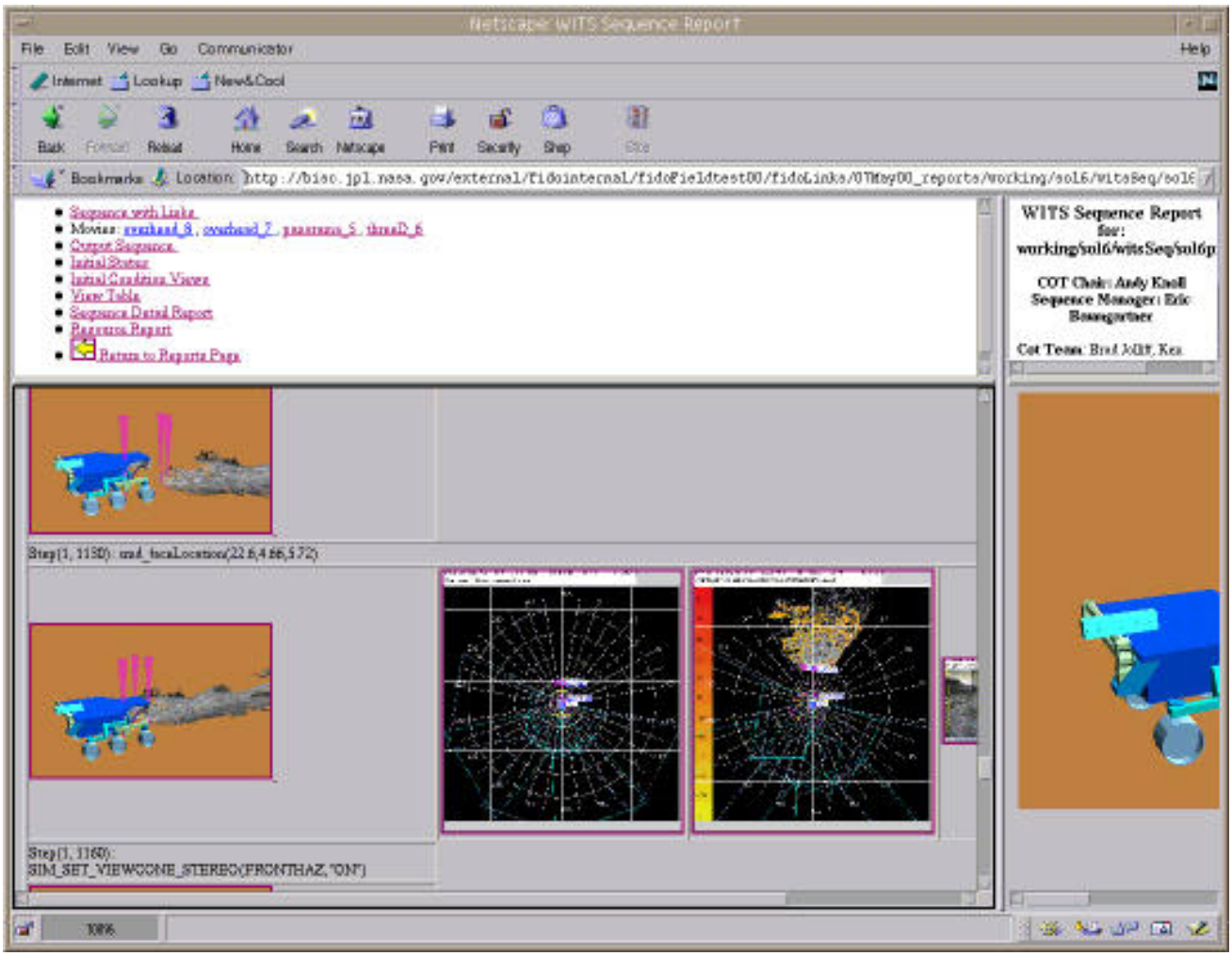

Figure 7. Sequence Report View Table

mechanism is needed which will capture the goals of the scientists, notes from meetings, explanation of reasons for commands in the sequence, and save diagrams which were used in planning. This information will be needed for specific sequences as well as longer term plans, e.g., multi-day, week-long and month-long plans.

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